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Comparison of treatment effects of herbst and advansync appliances on hyoid bone position and cervical posture in skeletal class II malocclusion – A prospective randomized clinical trial

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ABSTRACT

Background : Mandibular retrusion is the most common cause of Class II Division 1 malocclusion, which needs correction of the underlying skeletal discrepancy. The objective of this study was to evaluate the Hyoid bone position and cervical posture changes following treatment with two fixed functional appliances - Herbst and Advansync^{TM} (Ormco, Orange, CA, USA) appliances in skeletal Class II malocclusion using pre and post treatment lateral cephalograms.

Materials and Methods: For this randomized controlled trial, 40 patients (21males and 19 females) were divided into two groups Group I, Herbst Appliance group (mean age: 12.6 +/- 0.67 years) and Group II, Advansync^{TM} group (mean age: 12.8 +/- 0.66yrs). Pre and post-treatment (after appliance therapy of 8 months duration) lateral cephalograms were evaluated using Planmeca Romexis software 5.0.0.R version for hyoid bone position and cervical posture changes.

Results: The Hyoid bone had displaced anteriorly by 1.64 mm in Group I and in Group II by 1.97 mm. There was downward displacement of hyoid bone by 1.73 mm in Group I and 2.03 mm in Group II with reference to the Frankfort horizontal (FH) plane. The Mandibular plane-Odontoid process tangent angle used for determining upper cervical posture decreased by 7.13^{o} in Group I, while by 0.33^{o} in Group II.

Conclusion: This study concluded that both Herbst and Advansync appliances showed an improvement in hyoid bone position and the cervical posture while Advansync appliance demonstrated greater uprighting of cervical posture which was statistically significant.

1. Introduction

The primary objective of an orthodontist is to ameliorate the aesthetics as well as function of an individual which is compromised in cases of malocclusions. Malocclusion can manifests itself in any of the three dimensions namely sagittal, vertical and transverse or can be a combination of discrepancy in more than one dimension. The second most common type of malocclusion is Class II malocclusion having worldwide prevalence rate of approximately 15% and that of 1.9% to 15% in Indian population.[1,2] Class II malocclusion cannot corrects itself with the ongoing growth, hence some intervention needs to be performed for treating the underlying skeletal cause which provides maximum benefits when performed during the peak of growth spurt. Growth modification procedures can successfully results in anterior positioning of the mandible.[3]

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Hyoid bone is a U-shaped structure situated in the anterior neck. It lies between chin and thyroid cartilage, approximately at the level of mandibular base. However, unlike other bones, hyoid do not have direct articulation with surrounding bones but is connected to the mandible via ligamentous and muscular attachments such as geniohyoid, mylohyoid and anterior belly of digastrics muscles. It has been cited in the literature that hyoid bone position alters with any change in position of mandible.[4–6] Erdem D[7] in their study reported significant correlations of hyoid bone position with airway, tongue and mandibular posture. It is postulated that cervical posture also changes with the anterior movement of mandible.

Lateral cephalograms are routinely used in orthodontics. Besides their contribution in diagnosing and determining orthodontic treatment changes, they can also be used to investigate the tongue, soft palate, and other supporting structures such as the mandible, hyoid bone and cervical posture changes. The skeletal and profile-changing effects of functional orthodontic appliances in Class II patients are widely documented in literature. But, none of these reports have specifically addressed changes occurring in both the hyoid position and cervical posture following fixed functional appliance therapy. Hence, the objective of the present study was to evaluate treatment effects of Herbst and Advansync appliances on hyoid bone position and cervical posture in skeletal Class II malocclusion.

2. Materials and Methods

The present study was conducted after the approval from Institutional Ethical committee (Approval No.: SGTU / Exam / SCY_17-18/332 dated 30^{th} November 2019).

This was a parallel-group trial and the patients were selected from the Department of Orthodontics, SGT University after taking Informed consent from the parents/guardians of all patients in the local language (Hindi) and/or English. Patients included in the study fulfills the criteria of having CVMI (Cervical Vertebral Maturation Index) stages 3 and 4, skeletal class II malocclusion, a retrognathic mandible, and positive visual treatment objective (VTO). Patients having any congenital syndrome or systemic disease, poor oral hygiene, or missing first permanent molars were excluded from the study. The total sample of 40 patients was divided into two groups for Herbst and AdvanSync appliance functional therapy. Sample size was calculated using power analysis evaluation SPSS version 20 (SPSS statistics, IBM, Armonk, NY, USA). A sample size of 17 in each group was required to attain 80% power of the study at 95% confidence level and a significance level at 0.05. Assuming 10% attrition to follow-up, the sample size was rounded to 20 per group.

Group I: 20 skeletal class II patients (10 male, 10 female; mean age 12.6 ± 0.67 years) were treated with the Herbst appliance (American Orthodontics, Sheboygan, WI, USA).

Group II: 20 skeletal class II patients (11 male, 9 female; mean age 12.8 ± 0.66 years) were treated with the AdvanSync™ 2 appliance (Ormco, Brea, CA, USA).

Both group I and II patients were given one of the two fixed functional appliances. The software randomizer.org was used for randomization process in which serial numbers were assigned randomly to the patients. All patients were followed up and evaluated for molar relation, canine relation, overjet, overbite for a maximum duration of 8 months of appliance therapy until a class I molar was achieved. Pre- and posttreatment lateral cephalograms were taken and traced using Romexis® software (5.0.0.R version, Planmeca, Helsinki, Finland).

The descriptive statistics of the two groups has been summarized in Table 1 which showed that there was no significant difference in pre- treatment variables (CVMI, Age, Incisor-Mandibular plane angle -IMPA, Point A, Nasion, Point B (ANB) angle etc.) used in this study and the groups were well matched before treatment to eliminate any bias.

The landmarks and parameters used in the study (as reported in the literature)[8] are described in Table 2.

Pre and post functional treatment lateral cephalograms were traced for the evaluation of four hyoid bone parameters as shown in Figure 1 and seven cervical posture parameters which are further divided into upper cervical posture parameters as depicted in Figure 2 & middle cervical posture parameters as shown in Figure 3.

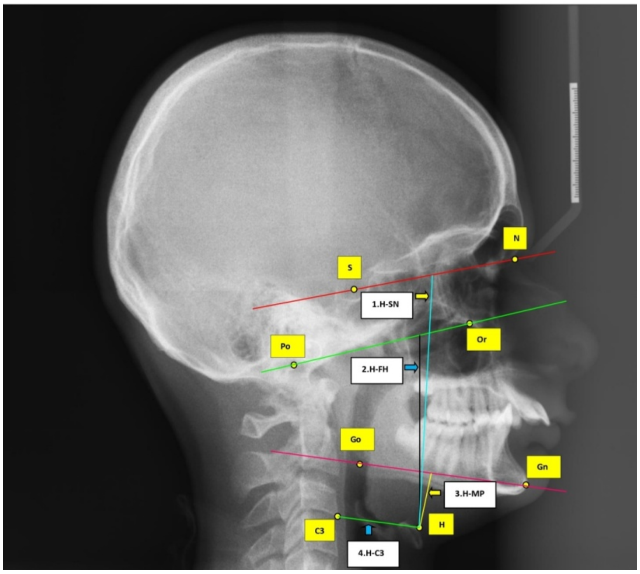

Figure 1: Measurements used for determining Hyoid bone position (1) H-SN, (2) H-FH, (3) H-MP, (4) H-C3

2.1. Statistical analysis

Data collected was tabulated using Microsoft excel and analysed using *SPSS (Statistical Package for Social*

Table 1: Pre-treatment statistical comparison for Group I and Group II

VARIABLES		**Group I (Herbst)**	**Group II (AdvanSync 2)**	**p-value**
Sample Size		20	20	—
Age		12.6 + 0.67	12.8 +0.66	0.605
CVMI	Stage 3 Stage 4	9 (45%) 11 (55%)	8 (40%) 12(60%)	0.749
Gender	Male Female	10 (47.6%) 10 (52.6%)	11(52.4%) 9 (47.4%)	0.752
Upper gonial angle (º)		54.43 + 4.85	51.78 + 4.86	0.245
Lower gonial angle (º)		68.02 + 5.16	67.54 + 4.5	0.498
IMPA (º)		105.24 + 5.84	104.75 + 6.98	0.809
ANB (º)		6.80 + 1.68	6.83 + 1.82	0.946

Not Significant- p> 0.05; Significant(*) p< 0.05; Highly Significant(**) p< 0.01,Very Highly Significant(***) p< 0.001

Table 2: Landmarks andparameters used in the study

1.	**H**	**Hyoidale**
2.	Go	Gonion
3.	Gn	Gnathion
4.	ANS	Anterior nasal spine
5.	PNS	Posterior nasal spine
6.	SN	Sella-nasion
7.	FH	Frankfort-horizontal plane
8.	MP	Mandibular plane (Go-Gn)
9.	PP	Palatal plane (ANS-PNS)
10.	C3	Third cervical vertebrae
11.	H-SN	Hyoid-Sella nasion distance
12.	H-FH	Hyoid-Frankfort horizontal distance
13.	H-MP	Hyoid-Mandibular plane distance
14.	H-C3	Hyoid-Third cervical vertebrae distance
15.	OPT	The Odontoid process tangent (drawn through the most postero inferior point on the second cervical vertebrae)
16.	SN-OPT	Sella nasion-Odontoid process tangent angle
17.	PP-OPT	Palatal plane-Odontoid process tangent angle
18.	MP-OPT	Mandibular plane-Odontoid process tangent angle
19.	CVT	The Cervical vertebral tangent (tangent passing through the most posteroinferior point of fourth cervical vertebrae)
20.	SN-CVT	Sella nasion-Cervical vertebral tangent angle
21.	PP-CVT	Palatal plane-Cervical vertebral tangent angle
22.	MP-CVT	Mandibular plane-Cervical vertebral tangent angle
23.	OPT-CVT	Odontoid process tangent-Cervical vertebral tangent angle
24.	H-SN perpendicular (mm)	Linear distance along a perpendicular from H to the SN plane
25.	H-FH perpendicular (mm)	Linear distance along a perpendicular from H to the Frankfort plane
26.	H-MP perpendicular (mm)	Linear distance along a perpendicular from H to the Mandibular plane (Go-Gn)
27.	H-C3 (mm)	Linear distance between H and C3
28.	SN-OPT (°)	The anterior and inferior angle created by OPT with Sella-nasion plane (SN)
29.	PP-OPT (°)	The anterior and inferior angle created by OPT with Palatal plane (PP)
30.	MP-OPT (°)	The anterior and inferior angle created by OPT with Mandibular plane (SN-GoGn)
31.	SN-CVT (°)	The anterior and inferior angle created by CVT with the Sella-nasion plane (SN)
32.	PP-CVT (°)	The anterior and inferior angle created by CVT with Palatal plane (PP)
33.	MP-CVT (°)	The anterior and inferior angle created by CVT with Mandibular plane (SN-GoGn)
34.	OPT-CVT (°)	Angle formed between OPT and CVT

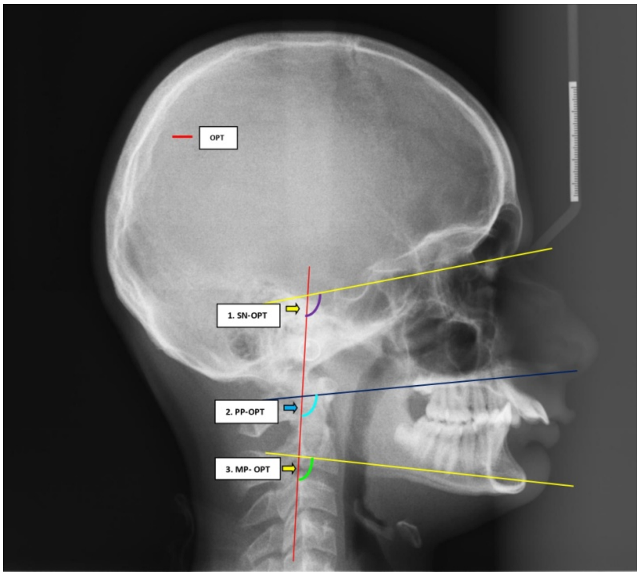

Figure 2: Angular measurements used for determining Upper cervical posture (1) SN-OPT, (2) PP-OPT, (3) MP-OPT

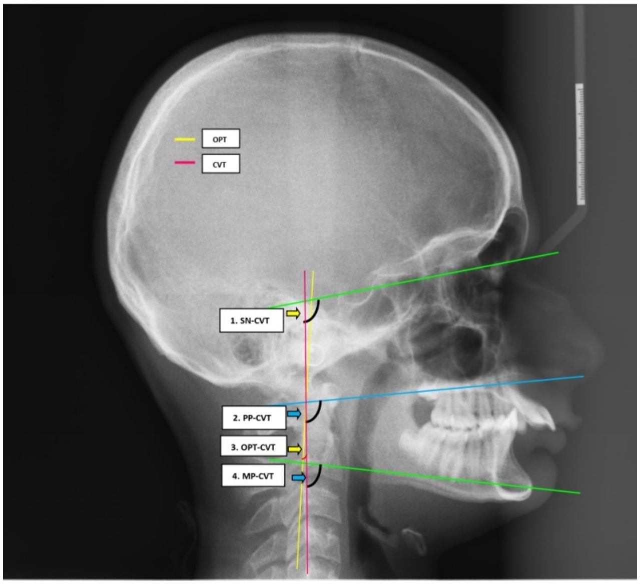

Figure 3: Angular measurements used for determining Middle cervical posture (1) SN-CVT, PP-CVT, (3 OPT-CVT, (4 MP-CVT)

Sciences) version 20 and Epi-info version 3.0 [IBM SPASS statistics (IBM corp. Armonk, NY, USA released 2011)]. Various parameters were assessed on the lateral cephalogram using the Romexis software 5.0.0.R version which is precalibrated. Descriptive statistics of the explanatory and outcome variables were calculated by the mean, standard deviation for the quantitative variables, and frequency and proportion for qualitative variables Comparison of means of various parameters between two groups was carried out using Independent sample t-test. Comparison of means of various parameters at baseline and post-intervention within the groups were carried out using Paired t-test ($p<0.05$). Intraexaminer reliability and interexaminer reliability were assessed calculating Cohen's kappa (κ) which was found to be in the range of 0.85 to 0.90 for all the parameters assessed.

3. Results

Lateral cephalograms (pre and post-treatment) of 40 patients (21 males and 19 females) in CVMI stages of 3 (17, 42.5%) and 4 (23, 57.5%) were evaluated for hyoid bone and cervical postural changes.

In Group I, hyoid bone moved forward by 1.64 mm and in Group II by 1.97 mm. There was downward displacement of hyoid bone by 1.73 mm in Group I and 2.03 mm in Group II with reference to the FH plane. The increase in H-MP distance was 2.14 mm in Group I and 0.45 mm in Group II. The mean differences of hyoid bone measurements were statistically insignificant on intergroup comparison between Group I and II as shown in Table 3.

Regarding the upper cervical posture, SN-OPT angle decreased by 6.84^{o}in Group I and by 4.62^o in Group II. The MP-OPT angle decreased by 7.13^o in Group I, while by 0.33^{o}in Group II, which was highly significant. For middle cervical posture, SN-CVT angle decreased by 5.09^o in Group I while by 3.78^o in Group II. Palatal plane-Cervical vertebral tangent (PP-CVT) and MP-CVT angle also decreased by 5.31^o and 4.24^o in Group I, in contrast to a decrease of 4.41^o and 3.32^o in Group II respectively. For the OPT-CVT angle, an increase of 0.39^{o}was observed in Group II and a decrease by 0.09^o in Group I, although this was statistically not significant ($p> 0.05$) as shown in Table 4 **.**

4. Discussion

Over the years, the horizon of functional appliances has broadened in the specialty of orthodontics. They act as arsenal that can accomplish results which are not possible without such appliances. Skeletally, a prognathic maxilla, a retrognathic mandible, or a combination of the two can be a possible etiologic factor for Class II malocclusion, treatment of which can ranges from camouflage to surgical procedures. The maximum effects of functional jaw orthopedics can be extracted during the pubertal growth spurt of an individual. Fixed functional appliances transmit continuous forces as compared to removable appliances that transmit intermittent forces.

Hyoid bone position is not stagnant and alters with the mandibular position.[9] Any changes occurring in the position of mandible either physiologically, surgically or by orthodontic treatment has potential to produce hyoid bone positional changes as well.[10] Association between inferior and posterior hyoid bone position with retrognathically

Table 3: Intergroup comparison of mean difference values of Hyoid bone position between Group I (Herbst) and II (Advan Sync 2)

Variables	Group I		Group II		Independent sample t- test
	Mean	SD (+)	Mean	SD (+)	p-value
H-SN	-4.360	9.278	0.955	11.446	0.115
H-FH	1.735	8.279	2.035	9.654	0.917
H-MP	2.144	6.028	0.45	3.766	0.294
H-C3	1.645	3.215	1.975	4.856	0.801

Not Significant- p> 0.05;

Table 4: Intergroup comparison of upper & middle cervical posture treatment changes of Group I (Herbst) and Group II (AdvanSync 2) using Independent Sample t-test.

Variables	Group I		Group II		Independent sample t-test
	Mean	SD (+)	Mean	SD (+)	p-value
SN-OPT	-6.842	4.484	-4.628	7.166	0.249
PP-OPT	-5.197	4.739	-4.544	7.548	0.745
MP-OPT	-7.131	4.620	-0.337	5.822	0.000***
SN-CVT	-5.09	4.794	-3.78	4.201	0.364
PP-CVT	-5.316	5.870	-4.417	6.783	0.657
MP-CVT	-4.246	4.158	-3.32	5.827	0.566
OPT-CVT	-0.093	1.375	0.398	1.128	0.224

Not Significant- p> 0.05;Very Highly Significant(***) p< 0.001

positioned mandible is reported by Tikku et al.[11] Significant hyoid bone positional changes are noticed when there exists a skeletal discrepancy rather than the dentoalveolar malrealtionship.

Various researchers have studied the inter-relationship between craniofacial morphology and cervical spine posture.[12,13] The posture of head and neck is seen to be related with various factors, such as age, sex and facial form characteristics like mandibular deviation,[14] and mandibular size.[15,16] An association has been observed between cervical spine and the mandibular size, morphology of craniofacial structures and mandibular divergence.[17] From a research view point, it is well documented that static alignment of cervical angle changes following insertion of an oral appliance.[18] However evidence regarding long-term postural changes produced by oral appliances is still lacking. Weber P et al. (2012)[16] found lateral cephalogram to be one of the most accurate methods for evaluation of cranio-cervical posture.

The patients treated in our study showed a downward and forward movement of hyoid bone. In Group I, a significant forward movement in H-C3 distance of 1.64 +/- 3.21 mm has been observed. A forward displacement of hyoid bone by 1.97 +/- 4.85 mm was also observed in Group II, but it was not significant as shown in Fig. 4a**.** On intergroup comparison, the difference found was statistically insignificant. The results of this study were in accordance with the retrospective cephalometric study conducted by Bavbek et al. (2016)[19] who concluded that the hyoid bone moved significantly forward following treatment with forsus fatigue resistant device.

For Group I, there was a mean increase in H-FH and H-MP by 1.73 +/- 8.27 mm and 2.14 +/- 6.02 mm respectively. For Group II also, a mean increase in H-FH and H-MP distance by 2.03 +/- 9.65 mm and 0.45 +/- 3.76 mm respectively has been observed indicating a downward displacement of hyoid bone. Although, this increase in both the groups was found statistically insignificant as shown in Figure 4 b, 4c**.** Similar to our findings, Gu M et al. (2020)[20] reported that hyoid bone moved significantly forward and downward following treatment with Herbst appliance.

In this study, significant decrease was observed in H-SN by 4.36 mm (p< 0.05) following treatment in Group I. On contrary, an increase by 0.95 mm was observed in Group II, although this was found statistically insignificant as shown in Figure 4 d**.** The findings of the present study are similar with the study of Hourfar et al. (2021)[21] who concluded that posterior airway space is enlarged and the epiglottis moves anteriorly and downwards with fixed functional appliances. On contrary, Ozdemir et al. (2014)[22] reported that in patients treated with semi-rigid Herbst appliance, no hyoid bone positioning change occurs.

Mandibular advancement appliances brings dentoalveolar mesialization followed by adaptations in tongue posture and as a result hyoid bone moves forwardly and downwardly to a relatively stable vertical position. Similar conclusion was drawn by Dedhiya et al. (2020)[23] who reported statistically significant movement in horizontal and vertical planes after functional therapy. Verma et al. (2012)[24] and Ulusoy et al. (2014)[25] also found

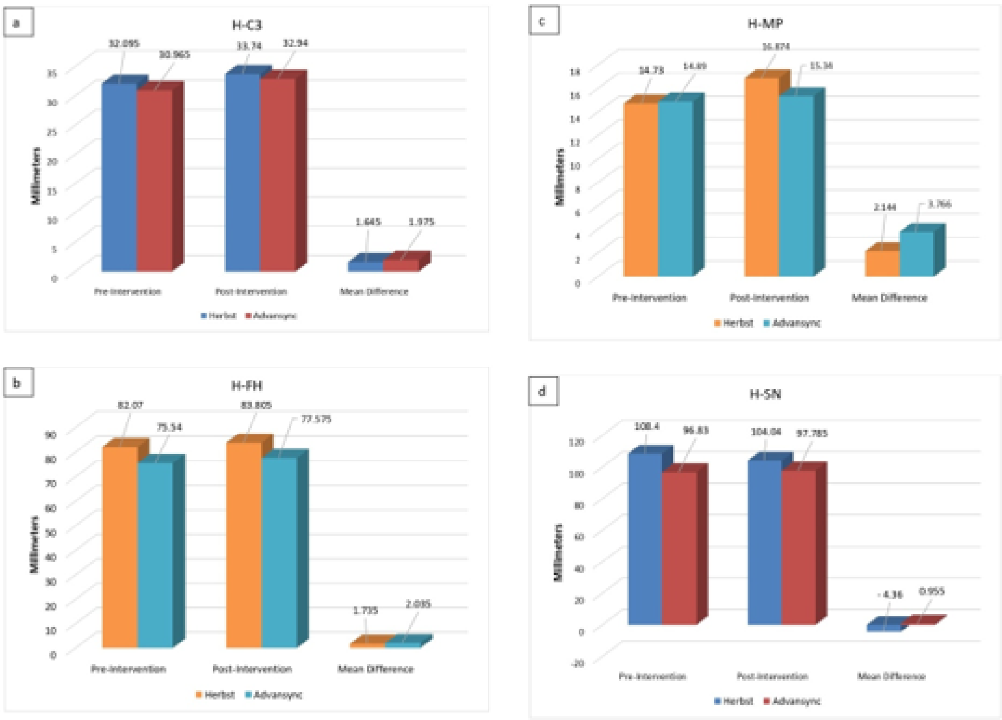

Figure 4: Mean difference of hyoid bone for (a) H-C3 (b) H-FH (c) H-MP (d) H-SN parameters

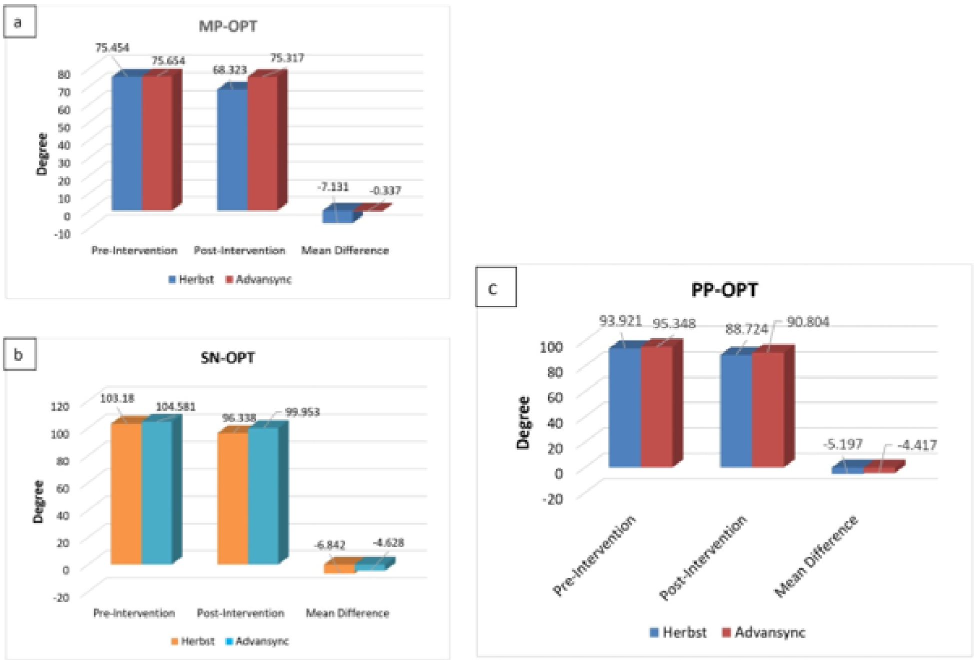

Figure 5: Mean difference in the upper cervical measurements for **(a)** MP-OPT **(b)** SN-OPT **(c)** PP-OPT parameters

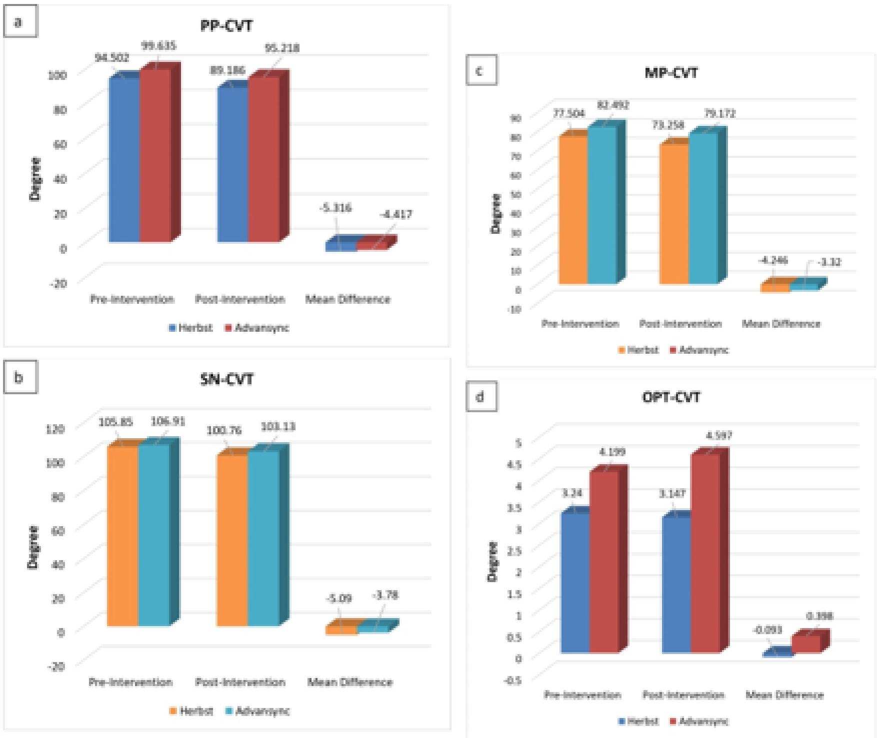

Figure 6: Mean difference of Middle cervical measurements for **(a)** PP-CVT **(b)** SN-CVT **(c)** MP-CVT (d) OPT-CVT parameters

anterior and downward hyoid bone movement in their studies. So, it can be inferred that hyoid bone positional change gets easily reflected in the adaptations occurring in tongue and mandibular position. Fixed functional appliances advances the mandible, following which the surrounding ligaments moves the hyoid bone in a forward direction as seen in our study which was by 1.64 +/- 3.21 mm (p=0.034) in Group I.

In present study, both the fixed functional appliances (Herbst and AdvanSync 2) had showed reduction in all the three upper cervical parameters (SN-OPT, PP-OPT and MP-OPT). Group I showed highest reduction in MP-OPT angle by 7.13+/- 4.62^o. While Group II had shown least decrease in MP-OPT angle by a mean of 0.33+/- 5.82^o as shown in Fig. 5a**.** The reduction in these angles indicates uprighting of the cervical spine posture. Decrease in SN-OPT angle by 6.8+/-4.4^o and 4.6+/- 7.1^o has been observed following treatment in Group I and Group II respectively (Figure 5 b)**.** The improvement in cervical posture was further reflected by a significant reduction in PP-OPT angle after treatment in Group I and Group II by 5.19+/-4.7^o and 4.5+/-7.5^{o}respectively as shown in Figure 5 c. The decrease of upper cervical parameters found in both the treatment group indicates the straightening/uprighting of upper cervical spine posture following functional appliance treatment but the effect was greater with AdvanSync 2 appliance.

Results of the present study are in accordance with those of Ohnmeib et al who noticed a significant straightening of the upper cervical column following the functional treatment.[26] On the contrary, Kamal et al. (2019)[8] found no change in the cranio-cervical angles in the twin block group and change in head extension angulation was observed with the growth of an individual.[8]

Decrease in all the middle cervical parameters in both Group I and Group II was observed with exception of OPT-CVT angle. The highest decrease in the PP-CVT angle by a mean of 5.31+/- 5.87^o and 4.41+/-6.78^o has been found in Group I and Group II respectively as shown in Figure 6 a**.** The decrease in cervical parameter values is indicating the uprighting effect on cervical posture after functional appliance treatment. In the present study, a decrease in SN-CVT angle by 5.09 +/- 4.79^o has been observed in Group I and 3.78+/- 4.20^o inGroup II (Figure 6 b).

The reduction in the middle cervical parameters in this study supports the uprighting effect produced by functional appliance on the cervical posture and a gain of more healthy and normal cervical spine curvature when correction of Class II malocclusion has been achieved with functional appliances. A mean decrease of 4.24+/- 4.15^o and 3.32+/- 5.82^{o}was observed in MP-CVT angle following treatment in Group I and Group II respectively as shown in Fig. 6c**.** Contrary to our findings, Tecco et al. (2005)[27] who evaluated the cervico-spinal column after treatment with the functional regulator Frankel II, reported a noticeable increase in the cervical angle values, which represent the relationship between the upper and lower segment of the cervical spinal column, in comparison to the control group. However, different from other cervical parameters, the OPT-CVT angle showed a mean decrease of 0.09+/- 1.37^o in Group I while an increase of 0.39+/- 1.12^{o}was observed after treatment in Group II as shown in Figure 6 d.

Aglarci et al. (2016)[28] reported an increase in OPT/CVT angle following functional appliance treatment, while the present study did not observed any such change. Alsheikho et al. (2021)[29] and Kamal et al[8] did not observed any change in cervical (OPT/CVT) angle, neither in functional appliance group nor in the control group. Class II malocclusion due to mandibular retrognathism experiences a greater forward inclination of cranio-cervical posture following the functional therapy as reported by Kamal and Fida. (2019)[8] Aglarci et al. (2016)[28] in their study observed improved sagittal relationships and an increase in cervical curvature after treatment with twin block appliance.Santander et al. (2014)[30] also reported an increase in cervical (OPT-CVT) angle after mandibular advancement appliance (MAA) treatment, hence it can be concluded that cervical alignment improves following MAA therapy.

It was observed by Ohmeib et al. (2014)[26] that prior to the orthodontic correction, an individual presents with altered cervical column inclination such as hyoperlordosis cervical spine, head retroflexion etc. If these cervical column alterations persists for a long period of time, this can led to worse consequences like hyoid descendence, decrease in pharyngeal size, persistant mouth breathing habit and further retrusion of mandibular. Therefore functional appliance treatment produces a favorable effect on the cervical posture.

The lateral cephalograms in this study either pre or post-treatment, were taken without the appliance inserted in the mouth which aimed to examine the real therapeutic effects after the correction of retrognathic mandible. So, due to this fact, the data in the current study can be considered as real changes in postural assessment after functional appliance therapy and not merely a mechanical effect of the oral appliance.

There exists a good amount of literature on hyoid bone positional changes following Herbst appliance but there is scarcity of literature on the treatment effects of AdvanSync 2 appliance on hyoid bone position. The literature on cervical spine posture changes following functional appliance treatment is available in abundance for variety of removable functional appliances but is sparsely available for fixed functional appliances and also for the comparative evaluation of effects of the commonly used Herbst and AdvanSync 2 appliances on hyoid bone position and cervical posture changes. So, this study focuses on comparing the effects of AdvanSync 2 and Herbst appliances on hyoid bone position and cervical spine posture.

The straightening of cervical spine posture is consistent with physiological growth as well This may be a limitation of this study, as part of the observed changes can be due to physiological growth so the cervical posture changes can be attributed to a combination of orthodontic treatment and ongoing growth independent of the conducted treatment. Also, in this study hyoid bone and cervical posture changes were not assessed after completion of treatment which can be another limitation. So, further studies with increased sample size, comparison with control sample to find out growth changes and evaluation of long term stability post fixed functional appliance therapy are suggested.

5. Conclusion

This study evaluated the treatment effects of Herbst and Advansync appliances on Hyoid bone position and Cervical posture in skeletal Class II malocclusion using lateral cephalograms. The forward displacement of hyoid bone was seen more in the Herbst group while the downward displacement was greater in Advansync group. Uprighting of cervical spine posture was observed in both the groups and greater uprighting was seen in the Advansync group.

6. Registration

This study was approved by the Ethical Committee (SGTU/Exam/SCY_17-18/332 dated 30th November 2019) and Registered in Clinical Trials Registry – India (CTRI/2021/02/031571 dated 25th Feb. 2021).

7. Sources of Funding

None.

8. Conflict of Interest

None.

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